National Aeronautics and Space Administration

Photosynthetic Spectra on Exoplanets

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Project Objective

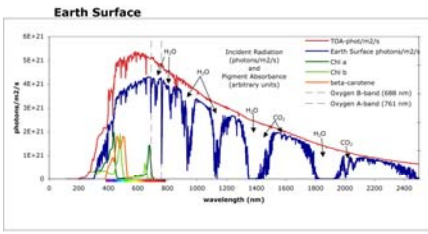
What plausible colors might future telescopes see for photosynthesis on exoplanets orbiting stars hotter or cooler than our Sun?

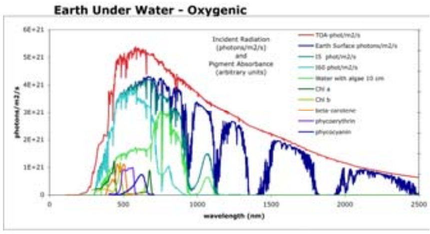
What kind of light spectrum will alien photosynthesizers see?

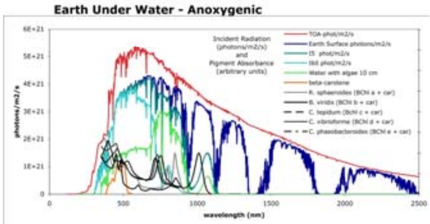
Recent Results

In papers published last year in the journal *Astrobiology*, we examined how photosynthetic pigments are adapted to solar radiation, and we simulated the light spectrum as would be seen by organisms living on exoplanets around F, K, quiescent M, and flaring M stars. We found:

- Green chlorophyll dominates on Earth because oxygen from photosynthesis itself shifted the Solar spectrum at the Earth's surface.
- Plants around F stars would likely absorb more in the blue.
- Plants around M stars could prefer the infrared and be anoxygenic.







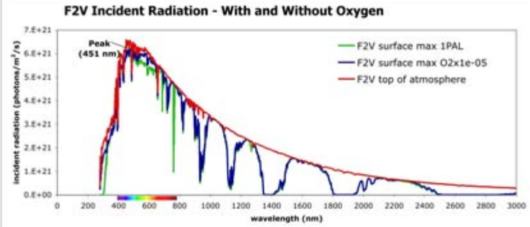
Land plants often get too much light, so they need only chlorophyll and carotenoid pigments to harvest mostly blue and red photons. The ozone Chappuis band in the visible region shifts the solar incident photon flux density to have peak photons in the red. Underwater, algae and cyanobacteria have extra pigments, phycobilins, to pick up more green and yellow photons. In deep, dark, anoxic waters, anoxgenic bacteria harvest leftover near-infrared photons and what little visible photons they can get.

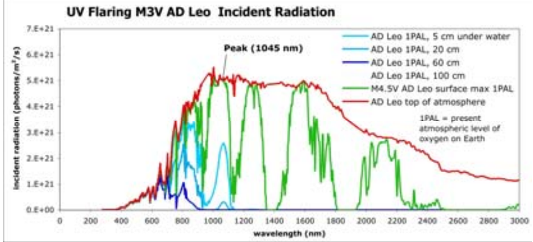
Project Description

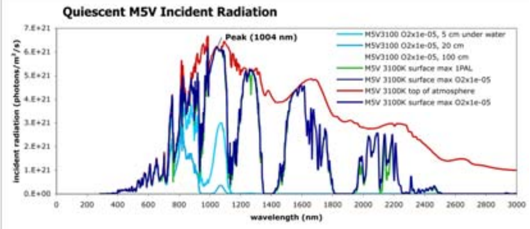
Photosynthesis on extrasolar planets will be adapted to a light spectrum from stars of other types than our Sun, filtered through a different atmosphere.

On Earth, we found these rules: pigments will preferentially absorb photons that are either the most abundant, the shortest available wavelength (most energetic), or longest available wavelength (where the photosynthetic reaction center operates). The available light spectrum is itself influenced by atmospheric inputs from photosynthesis: O_2 and O_3 shift solar radiation to have most photon in the red at the Earth's surface -- right where the oxygenic photosynthesis reaction center is.

We calculated the surface incident photon flux spectrum on Earth-like planets orbiting these star types: F, K, a quiescent M dwarf, and a UV flaring M star. Atmospheric composition, assuming Earth-like surface fluxes, with and without oxygen, was calculated with a photochemical model (Pavlov and Kasting, 2002) coupled to a radiative-convective model (Pavlov, et al., 2000). Incident light spectra were calculated with the high-resolution radiative transfer model, SMART (Meadows & Crisp, 1996; Crisp, 1997).







Oxygenic photosynthesis makes the light spectrum on F2V planets bluer, due to shifting by the ozone Chappuis band. Plants will have so much blue light, they might need suncreen like anthocyanin, but blue-colored. Life starting out on planets around young UV-flaring M stars will need to keep under water for protection. When the star matures and flares die down, no ozone shield will be needed on land. The dominant photosynthesis could be anoxygenic in the infrared.

Conclusions

- This work will help to interpret the data from NASA's Terrestrial Planet Finder and the European Space Agency's (ESA) Darwin missions for signs of photosynthetic life.
- Why are plants green? We offer a new explanation based on the coevolution of Earth photosynthesis with the atmosphere: oxygen from early oxgenic photosynthesis in the oceans gave green plants the competitive advantage on land. On planets around M stars, the competitive advantage could be in the infrared.

Publications and References

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